

Chapter Five

LAWS OF MOTION



MCQ I

- 5.1** A ball is travelling with uniform translatory motion. This means that
- (a) it is at rest.
 - (b) the path can be a straight line or circular and the ball travels with uniform speed.
 - (c) all parts of the ball have the same velocity (magnitude and direction) and the velocity is constant.
 - (d) the centre of the ball moves with constant velocity and the ball spins about its centre uniformly.
- 5.2** A metre scale is moving with uniform velocity. This implies
- (a) the force acting on the scale is zero, but a torque about the centre of mass can act on the scale.
 - (b) the force acting on the scale is zero and the torque acting about centre of mass of the scale is also zero.

- (c) the total force acting on it need not be zero but the torque on it is zero.
- (d) neither the force nor the torque need to be zero.

5.3 A cricket ball of mass 150 g has an initial velocity $\mathbf{u} = (3\hat{\mathbf{i}} + 4\hat{\mathbf{j}}) \text{ m s}^{-1}$ and a final velocity $\mathbf{v} = -(3\hat{\mathbf{i}} + 4\hat{\mathbf{j}}) \text{ m s}^{-1}$ after being hit. The change in momentum (final momentum-initial momentum) is (in kg m s^{-1})

- (a) zero
- (b) $-(0.45\hat{\mathbf{i}} + 0.6\hat{\mathbf{j}})$
- (c) $-(0.9\hat{\mathbf{i}} + 1.2\hat{\mathbf{j}})$
- (d) $-5(\hat{\mathbf{i}} + \hat{\mathbf{j}})$.

5.4 In the previous problem (5.3), the magnitude of the momentum transferred during the hit is

- (a) Zero (b) 0.75 kg m s^{-1} (c) 1.5 kg m s^{-1} (d) 14 kg m s^{-1} .

5.5 Conservation of momentum in a collision between particles can be understood from

- (a) conservation of energy.
- (b) Newton's first law only.
- (c) Newton's second law only.
- (d) both Newton's second and third law.

5.6 A hockey player is moving northward and suddenly turns westward with the same speed to avoid an opponent. The force that acts on the player is

- (a) frictional force along westward.
- (b) muscle force along southward.
- (c) frictional force along south-west.
- (d) muscle force along south-west.

5.7 A body of mass 2kg travels according to the law $x(t) = pt + qt^2 + rt^3$ where $p = 3 \text{ m s}^{-1}$, $q = 4 \text{ m s}^{-2}$ and $r = 5 \text{ m s}^{-3}$.

The force acting on the body at $t = 2$ seconds is

- (a) 136 N
- (b) 134 N
- (c) 158 N
- (d) 68 N

- 5.8** A body with mass 5 kg is acted upon by a force $\mathbf{F} = (-3\hat{\mathbf{i}} + 4\hat{\mathbf{j}})$ N. If its initial velocity at $t = 0$ is $\mathbf{v} = (6\hat{\mathbf{i}} - 12\hat{\mathbf{j}})$ m s⁻¹, the time at which it will just have a velocity along the y-axis is
- never
 - 10 s
 - 2 s
 - 15 s
- 5.9** A car of mass m starts from rest and acquires a velocity along east $\mathbf{v} = v\hat{\mathbf{i}}$ ($v > 0$) in two seconds. Assuming the car moves with uniform acceleration, the force exerted on the car is
- $\frac{mv}{2}$ eastward and is exerted by the car engine.
 - $\frac{mv}{2}$ eastward and is due to the friction on the tyres exerted by the road.
 - more than $\frac{mv}{2}$ eastward exerted due to the engine and overcomes the friction of the road.
 - $\frac{mv}{2}$ exerted by the engine.

MCQ II

- 5.10** The motion of a particle of mass m is given by $x = 0$ for $t < 0$ s, $x(t) = A \sin 4\pi t$ for $0 < t < (1/4)$ s ($A > 0$), and $x = 0$ for $t > (1/4)$ s. Which of the following statements is true?
- The force at $t = (1/8)$ s on the particle is $-16\pi^2 A m$.
 - The particle is acted upon by an impulse of magnitude $4\pi^2 A m$ at $t = 0$ s and $t = (1/4)$ s.
 - The particle is not acted upon by any force.
 - The particle is not acted upon by a constant force.
 - There is no impulse acting on the particle.
- 5.11** In Fig. 5.1, the co-efficient of friction between the floor and the body B is 0.1. The co-efficient of friction between the bodies B and A is 0.2. A force \mathbf{F} is applied as shown

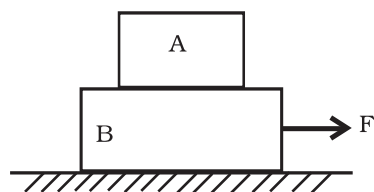


Fig. 5.1

on B. The mass of A is $m/2$ and of B is m . Which of the following statements are true?

- (a) The bodies will move together if $F = 0.25 mg$.
- (b) The body A will slip with respect to B if $F = 0.5 mg$.
- (c) The bodies will move together if $F = 0.5 mg$.
- (d) The bodies will be at rest if $F = 0.1 mg$.
- (e) The maximum value of F for which the two bodies will move together is $0.45 mg$.

5.12 Mass m_1 moves on a slope making an angle θ with the horizontal and is attached to mass m_2 by a string passing over a frictionless pulley as shown in Fig. 5.2. The co-efficient of friction between m_1 and the sloping surface is μ .

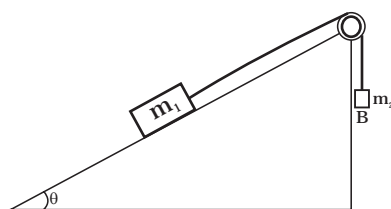


Fig. 5.2

Which of the following statements are true?

- (a) If $m_2 > m_1 \sin \theta$, the body will move up the plane.
- (b) If $m_2 > m_1 (\sin \theta + \mu \cos \theta)$, the body will move up the plane.
- (c) If $m_2 < m_1 (\sin \theta + \mu \cos \theta)$, the body will move up the plane.
- (d) If $m_2 < m_1 (\sin \theta - \mu \cos \theta)$, the body will move down the plane.

5.13 In Fig. 5.3, a body A of mass m slides on plane inclined at angle θ_1 to the horizontal and μ_1 is the coefficient of friction between A and the plane. A is connected by a light string passing over a frictionless pulley to another body B, also of mass m , sliding on a frictionless plane inclined at angle θ_2 to the horizontal. Which of the following statements are true?

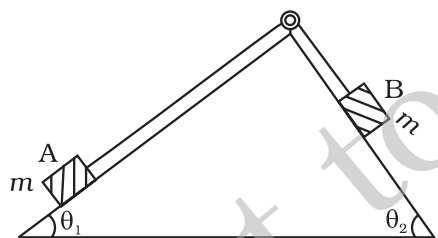


Fig. 5.3

- (a) A will never move up the plane.
- (b) A will just start moving up the plane when

$$\mu = \frac{\sin \theta_2 - \sin \theta_1}{\cos \theta_1}$$

- (c) For A to move up the plane, θ_2 must always be greater than θ_1 .
- (d) B will always slide down with constant speed.

5.14 Two billiard balls A and B, each of mass $50g$ and moving in opposite directions with speed of $5m s^{-1}$ each, collide and rebound with the same speed. If the collision lasts for $10^{-3}s$, which of the following statements are true?

- (a) The impulse imparted to each ball is $0.25 kg m s^{-1}$ and the force on each ball is $250 N$.

- (b) The impulse imparted to each ball is 0.25 kg m s^{-1} and the force exerted on each ball is $25 \times 10^{-5} \text{ N}$.
- (c) The impulse imparted to each ball is 0.5 N s .
- (d) The impulse and the force on each ball are equal in magnitude and opposite in direction.
- 5.15** A body of mass 10 kg is acted upon by two perpendicular forces, 6 N and 8 N . The resultant acceleration of the body is
- (a) 1 m s^{-2} at an angle of $\tan^{-1}\left(\frac{4}{3}\right)$ w.r.t. 6 N force.
- (b) 0.2 m s^{-2} at an angle of $\tan^{-1}\left(\frac{4}{3}\right)$ w.r.t. 6 N force.
- (c) 1 m s^{-2} at an angle of $\tan^{-1}\left(\frac{3}{4}\right)$ w.r.t. 8 N force.
- (d) 0.2 m s^{-2} at an angle of $\tan^{-1}\left(\frac{3}{4}\right)$ w.r.t. 8 N force.

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- 5.16** A girl riding a bicycle along a straight road with a speed of 5 m s^{-1} throws a stone of mass 0.5 kg which has a speed of 15 m s^{-1} with respect to the ground along her direction of motion. The mass of the girl and bicycle is 50 kg . Does the speed of the bicycle change after the stone is thrown? What is the change in speed, if so?
- 5.17** A person of mass 50 kg stands on a weighing scale on a lift. If the lift is descending with a downward acceleration of 9 m s^{-2} , what would be the reading of the weighing scale? ($g = 10 \text{ m s}^{-2}$)
- 5.18** The position time graph of a body of mass 2 kg is as given in Fig. 5.4. What is the impulse on the body at $t = 0 \text{ s}$ and $t = 4 \text{ s}$.

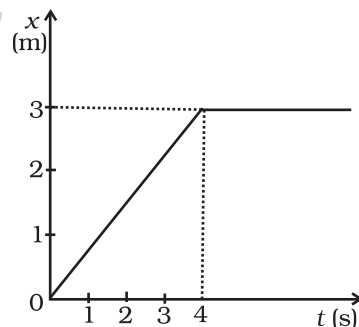


Fig. 5.4

- 5.19** A person driving a car suddenly applies the brakes on seeing a child on the road ahead. If he is not wearing seat belt, he falls forward and hits his head against the steering wheel. Why?
- 5.20** The velocity of a body of mass 2 kg as a function of t is given by $\mathbf{v}(t) = 2t \hat{\mathbf{i}} + t^2 \hat{\mathbf{j}}$. Find the momentum and the force acting on it, at time $t = 2\text{s}$.
- 5.21** A block placed on a rough horizontal surface is pulled by a horizontal force F . Let f be the force applied by the rough surface on the block. Plot a graph of f versus F .
- 5.22** Why are porcelain objects wrapped in paper or straw before packing for transportation?
- 5.23** Why does a child feel more pain when she falls down on a hard cement floor, than when she falls on the soft muddy ground in the garden?
- 5.24** A woman throws an object of mass 500 g with a speed of 25 m s⁻¹.
- (a) What is the impulse imparted to the object?
- (b) If the object hits a wall and rebounds with half the original speed, what is the change in momentum of the object?
- 5.25** Why are mountain roads generally made winding upwards rather than going straight up?

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- 5.26** A mass of 2kg is suspended with thread AB (Fig. 5.5). Thread CD of the same type is attached to the other end of 2 kg mass. Lower thread is pulled gradually, harder and harder in the downward direction so as to apply force on AB. Which of the threads will break and why?
- 5.27** In the above given problem if the lower thread is pulled with a jerk, what happens?
- 5.28** Two masses of 5 kg and 3 kg are suspended with help of massless inextensible strings as shown in Fig. 5.6. Calculate T_1 and T_2 when whole system is going upwards with acceleration = 2 m s⁻² (use $g = 9.8 \text{ m s}^{-2}$).

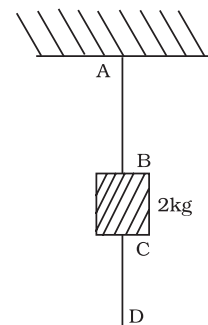


Fig. 5.5

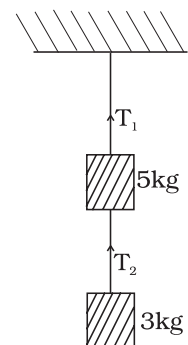


Fig. 5.6

- 5.29** Block A of weight 100 N rests on a frictionless inclined plane of slope angle 30° (Fig. 5.7). A flexible cord attached to A passes over a frictionless pulley and is connected to block B of weight W . Find the weight W for which the system is in equilibrium.

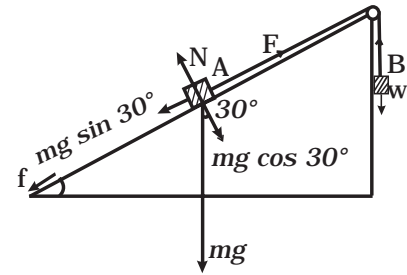


Fig. 5.7

- 5.30** A block of mass M is held against a rough vertical wall by pressing it with a finger. If the coefficient of friction between the block and the wall is μ and the acceleration due to gravity is g , calculate the minimum force required to be applied by the finger to hold the block against the wall?
- 5.31** A 100 kg gun fires a ball of 1 kg horizontally from a cliff of height 500 m. It falls on the ground at a distance of 400 m from the bottom of the cliff. Find the recoil velocity of the gun. (acceleration due to gravity = 10 m s^{-2})
- 5.32** Figure 5.8 shows (x, t) , (y, t) diagram of a particle moving in 2-dimensions.

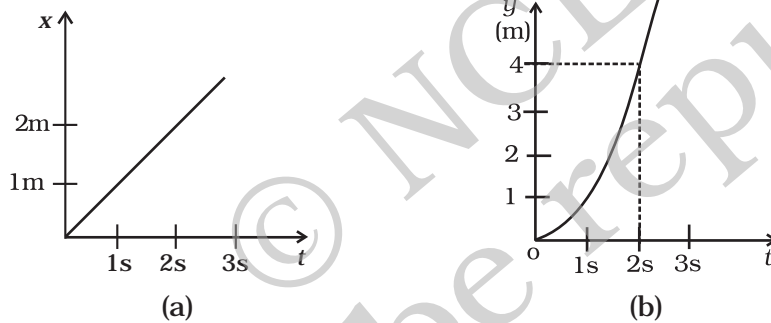


Fig. 5.8

If the particle has a mass of 500 g, find the force (direction and magnitude) acting on the particle.

- 5.33** A person in an elevator accelerating upwards with an acceleration of 2 m s^{-2} , tosses a coin vertically upwards with a speed of 20 m s^{-1} . After how much time will the coin fall back into his hand? ($g = 10 \text{ m s}^{-2}$)

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- 5.34** There are three forces \mathbf{F}_1 , \mathbf{F}_2 and \mathbf{F}_3 acting on a body, all acting on a point P on the body. The body is found to move with uniform speed.
- Show that the forces are coplanar.
 - Show that the torque acting on the body about any point due to these three forces is zero.

5.35 When a body slides down from rest along a smooth inclined plane making an angle of 45° with the horizontal, it takes time T . When the same body slides down from rest along a rough inclined plane making the same angle and through the same distance, it is seen to take time pT , where p is some number greater than 1. Calculate the co-efficient of friction between the body and the rough plane.

5.36 Figure 5.9 shows (v_x, t) , and (v_y, t) diagrams for a body of unit mass. Find the force as a function of time.

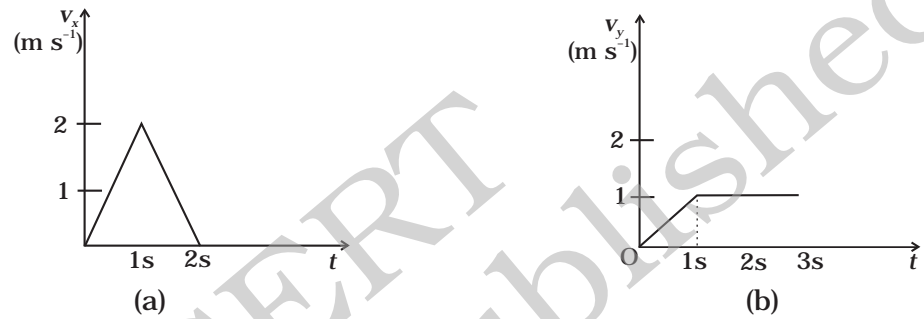


Fig. 5.9

5.37 A racing car travels on a track (without banking) ABCDEFA (Fig. 5.10). ABC is a circular arc of radius $2R$. CD and FA are straight paths of length R and DEF is a circular arc of radius $R = 100$ m. The co-efficient of friction on the road is $\mu = 0.1$. The maximum speed of the car is 50 m s^{-1} . Find the minimum time for completing one round.

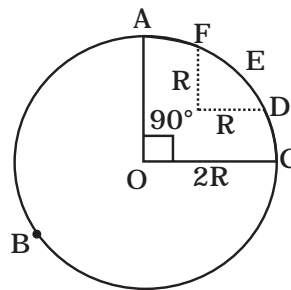


Fig. 5.10

5.38 The displacement vector of a particle of mass m is given by $\mathbf{r}(t) = \hat{\mathbf{i}} A \cos \omega t + \hat{\mathbf{j}} B \sin \omega t$.

- Show that the trajectory is an ellipse.
- Show that $\mathbf{F} = -m\omega^2 \mathbf{r}$.

- 5.39** A cricket bowler releases the ball in two different ways
- giving it only horizontal velocity, and
 - giving it horizontal velocity and a small downward velocity.
- The speed v_s at the time of release is the same. Both are released at a height H from the ground. Which one will have greater speed when the ball hits the ground? Neglect air resistance.
- 5.40** There are four forces acting at a point P produced by strings as shown in Fig. 5.11, which is at rest. Find the forces \mathbf{F}_1 and \mathbf{F}_2 .

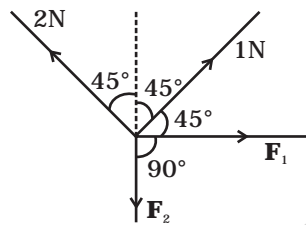


Fig. 5.11

- 5.41** A rectangular box lies on a rough inclined surface. The co-efficient of friction between the surface and the box is μ . Let the mass of the box be m .
- At what angle of inclination θ of the plane to the horizontal will the box just start to slide down the plane?
 - What is the force acting on the box down the plane, if the angle of inclination of the plane is increased to $\alpha > \theta$?
 - What is the force needed to be applied upwards along the plane to make the box either remain stationary or just move up with uniform speed?
 - What is the force needed to be applied upwards along the plane to make the box move up the plane with acceleration a ?
- 5.42** A helicopter of mass 2000kg rises with a vertical acceleration of 15 m s^{-2} . The total mass of the crew and passengers is 500 kg. Give the magnitude and direction of the ($g = 10 \text{ m s}^{-2}$)
- force on the floor of the helicopter by the crew and passengers.
 - action of the rotor of the helicopter on the surrounding air.
 - force on the helicopter due to the surrounding air.